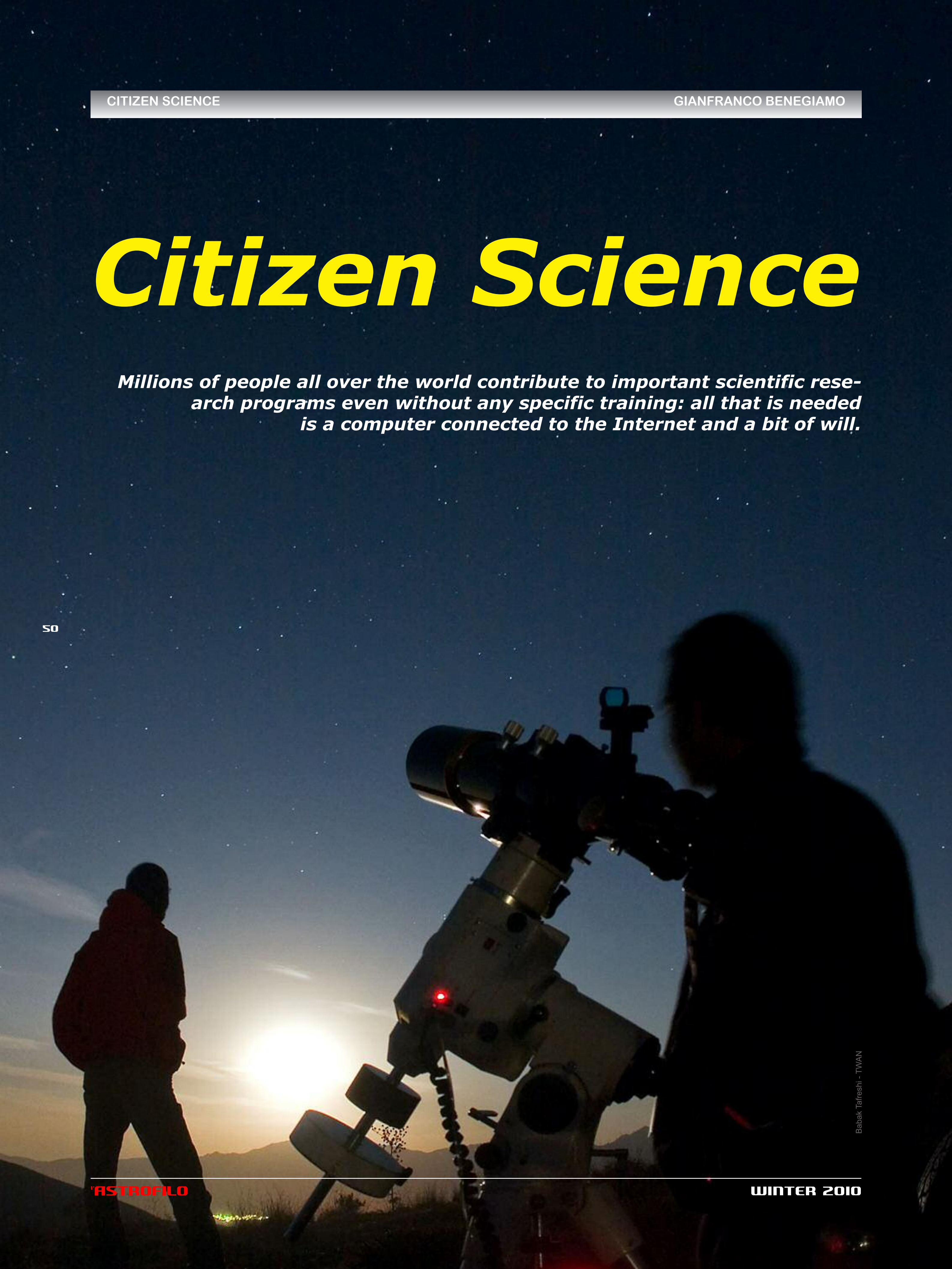
Citizen Science

Millions of people all over the world contribute to important scientific research programs even without any specific training: all that is needed is a computer connected to the Internet and a bit of will.



Babak Tafreshi - TWAN

Some members of the American Association of Variable Star Observers (AAVSO), one of the first associations that promoted Citizen Science in astronomy. The photograph was taken on 23rd November 1918 at the seventh annual general meeting.

Participating on mass in serious scientific research, like a team of millions of people playing the same sport despite very different levels of training, has become a reality thanks to the Internet. There were already various examples of serious research carried out by amateurs before the recent Internet revolution, but involving rather fewer people. One of the earlier initiatives was the Christian Bird Count, started in December 1900 by the National Audubon Society, that still today gathers important information on the bird populations of North America.
There is also a strong tradition in amateur astronomy; in fact the American Association of Variable Star Observers (AAVSO) have been recording the magnitudes of variable stars for almost a century. By collecting frequent and excellent quality measurements of a large number of stars, that would be otherwise impossible, the members have provided astronomers with a hugely important contribution.
These projects, which enroll the help of the public in the work of professionals, especially those in the natural sciences, have knock-on benefits to various communities. The researchers can rapidly execute tasks otherwise impossible, the volunteers have the satisfaction of contributing to research of interest to them, and teachers have another possibility of introducing students to real life scientific methods. Given the considerable increase of interest in this methodology, commonly referred to as "Citizen Science", we'll try to give a brief panorama of those projects involving the study of the heavens.

Research for all tastes

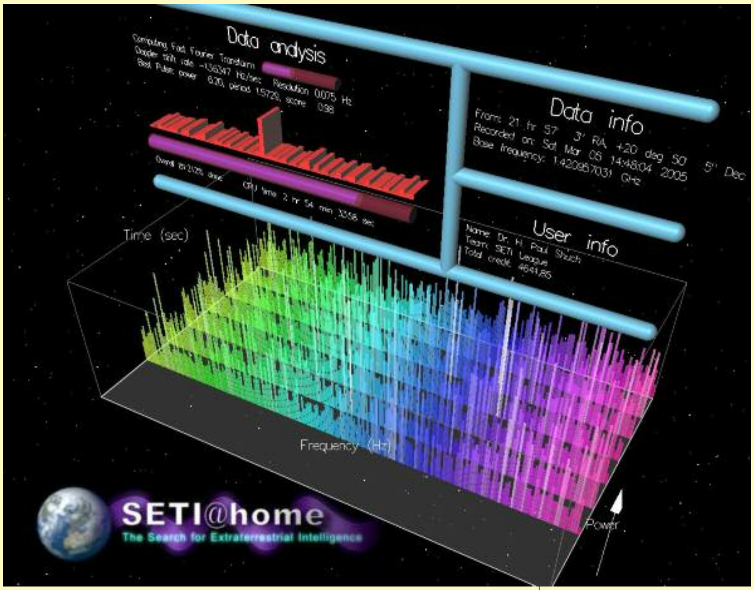
Citizen science projects can be divided into three broad categories: distributed computing, desktop research and field research. Distributed computing harnesses the potential of computers connected to the web. Purpose built programs, often in the form of screen savers, download their tasks in so called "work units", and, after a number of hours of analysis, return the results and download the next unit.
Virtually no effort is required by the volunteer, apart from the initial software installation, which perhaps gives rather little stimulus to investigate further the chosen project.
Rather more interesting, instead, are the projects that require some kind of active participation, either while seated

at a computer or looking at the sky. The aim of these is to distribute work to many thousands of people that would otherwise occupy researchers for a good fraction of their working lives. Many desk projects are based on the ability of the human eye to recognise patterns or relevant features in images, something with which even the most powerful computers struggle.

The incredible increase in registered participants in scientific fields, especially in the last ten years, is due to various factors, but most important are the diffusion of the Internet and the availability of engaging but user friendly computer programs. Also fundamental was the realisation by scientists that the millions of people connected to the web represented an enormous potential, both in terms of computing resources and intellect, that was available immediately and at zero cost. This has been decisive for some projects in dealing with the enormous quantity of data generated from both ground and space

Aerial view of the Laser Interferometer Gravitational-Wave Observatory, located near Livingston in Louisiana. The two perpendicular arms of the interferometer can be seen. [Courtesy LIGO]

based telescopes. Another reason for participating is that some funding bodies, for example the National Science Foundation in the States and the Natural Environment Research Council in the UK, stipulate that some fraction of grants awarded be spent on public outreach projects.

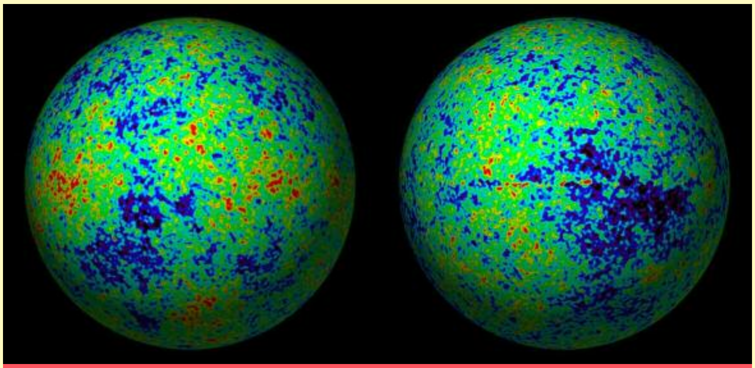


The screen saver SETI@Home activates automatically after some minutes of inactivity on the computer.

In certain fields of investigation, the fact that the tax payer's money is used to fund the research, makes both politicians and scientists realise the need to make the work appreciated by as many people as possible, possibly involving them directly. In this way they might see the worth of their investment.

Distributed computing

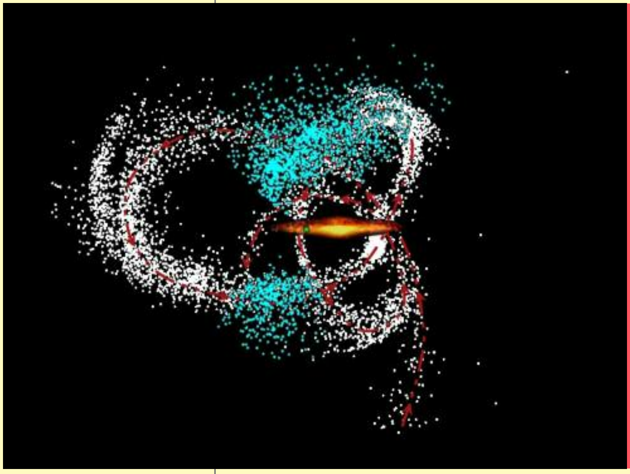
Amongst the first and most famous projects using distributed computing is SETI@Home, the Search for Extra-Terrestrial Intelligence, launched in May 1999. This is a screen saver, able to activate itself automatically when no activity is registered on the computer for a number of minutes. In this case the computing power is used to analyse radio signals coming from the depths of space, in search of alien messages. Brief fragments of the recordings from the Arecibo radio telescope, the largest single dish in the world, are distributed to volunteers to identify features that would be hard to explain with natural phenomena. The fascination of the project has resulted in more than five million volunteers worldwide, despite their completely passive role. This number has gained the project a place in the Guiness World Records!



The Cosmology@Home project aims to find the model that best describes the data from the Wilkinson Microwave Anisotropy Probe (WMAP), which measured the tiny temperature differences in the cosmic microwave background. [WMAP Science Team, NASA]

The identification of gravitational waves from continuous sources such as pulsars and binary black hole systems, is instead the goal of Einstein@Home. This distributed computing project analyses data from the Laser Interferometer Gravitational-Wave Observatory (LIGO). This is a gigantic laser light interferometer, with arms kilometers long, built to demonstrate the existence of gravitational waves, as hypothesised by the general theory of relativity. This is therefore a study of the particularly massive objects that produce these waves.

Along the same lines is Cosmology@Home, designed to identify the model that best reproduces the cosmological parameters measured by the Hubble Space Telescope and the Wilkinson Microwave Anisotropy Probe (WMAP), that mapped the cosmic microwave background. Thousands of possible solutions, each wrapped in single "work units", are distributed to participants. After some hours of analysis, at least on fairly fast machines, the result is sent automatically to the project server. Here, a learning algorithm called Pico, given a sufficiently large number of simulations, will produce other models of the Universe that approximate more closely that observed.



Representation of a model investigated in MilkyWay@Home. The location of the Sun is indicated with a green dot, while the blue points are the star trails from a nearby dwarf elliptical galaxy in the constellation of Sagittarius.

Lastly, MilkyWay@Home is a project, started in 2007, that aims to build an accurate dynamical model of the stellar streams in the immediate vicinity of the Galaxy, streams due to the partial penetration of a dwarf elliptical galaxy in the direction of Sagittarius.

Within a couple of years around 30,000 volunteers, in over 160 countries, contributed to a computing power of over 50 teraflops

The web page of the Galaxy Zoo project allows galaxies photographed by the SDSS to be classified with a few mouse clicks.

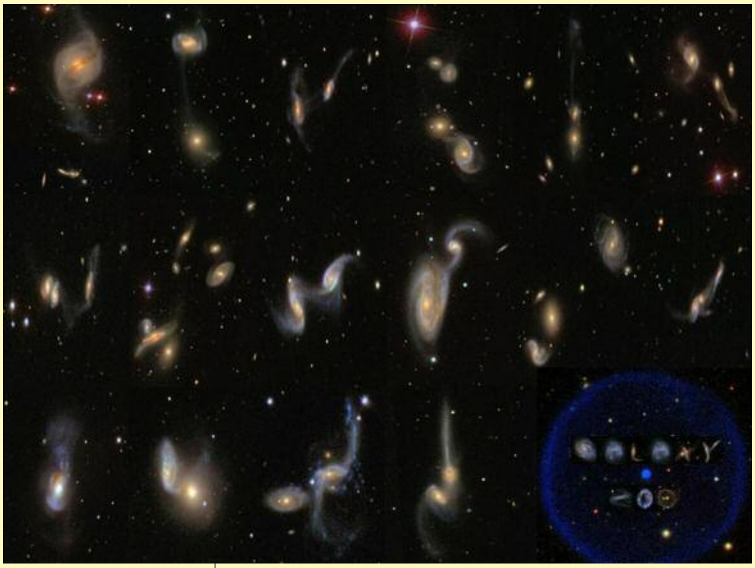
(flop stands for floating point operations per second, while the tera prefix means 10^{12}).

A new platform for distributed computing, called the Berkeley Open Infrastructure for Network Computing (BOINC) has been developed at the University of Berkeley. The first time this program is used one just needs to specify the desired project, amongst a wide range (including those mentioned above) and the rest is automatic. The software deals with connecting to the relevant web site from which to download data and to which the results will be sent. If the computer is turned off calculations are interrupted, but re-start when the computer is turned on again. The low priority assigned to the calculations ensures that no appreciable slowing down of the computer results when other programs are run.

Astronomy with the click of a mouse

The main surveys of the sky, like for example the Sloan Digital Sky Survey (SDSS), make available enormous quantities of data and images. A large part of the information is extracted automatically, creating catalogues with the characteristics of millions of objects. Some tasks, however, like the recognising and classification of galaxies, although easy for humans, remain relatively difficult for computers. To occupy hoards of astronomers in such an activity for years, distracting them from more important tasks, is obviously unthinkable. Such problems, however, find a solu-

The Galaxy Zoo project requests the help of volunteers to classify millions of galaxies photographed by the Sloan Digital Sky Survey telescope, shown in the image. [SDSS Team]



This mosaic shows some of the prettiest images of interacting galaxies sent to volunteers in the Galaxy Zoo project. [Richard Nowell & Hannah Hutchins]

tion in Citizen Science, that is becoming a point of contact between advanced research and ever larger sections of the general public.

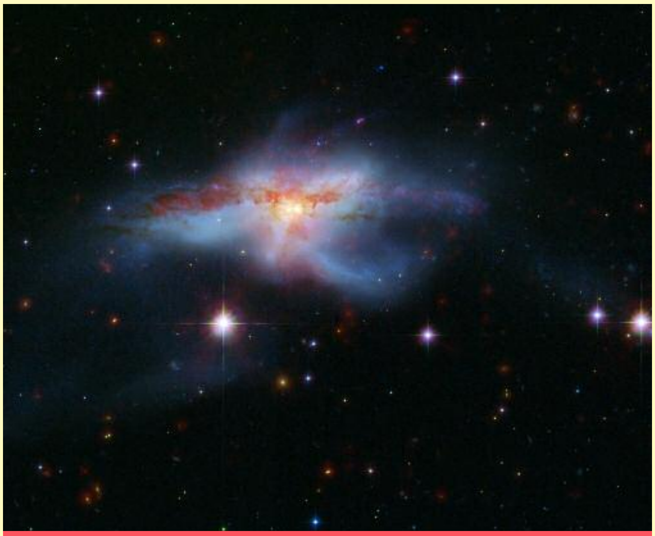
The Galaxy Zoo project, conceived to satisfy just this need, requests the contribution of volunteers to classify the galaxies photographed by the SDSS. Many of these objects, in fact, have never been looked at by the human eye. Step by step, with a few mouse clicks, you can distinguish an elliptical from a spiral galaxy, as well as decide whether the image contains an artifact or something unusual. An example of this, even if rather rare, happened to Hanny van Arkel, a young Dutch teacher, while checking a strange object near the galaxy IC 2497 (see insert on page 56).

Just in the first year of the project, 50 million images were distributed to 150,000 volunteers. By distributing a given image to more than one person it was established that the statistical accuracy of the classifications was similar to that carried out by professionals. The results gathered have already permitted the publication of several articles in leading journals.

The Stardust@Home project, rather, is designed to find the proverbial needle in the haystack. It's concerned with finding microscopic dust grains captured from comet 81P/Wild 2 in an ultra-low density, transparent material (aerogel), returned to Earth by NASA's Stardust mission. However, before starting the search for cometary fragments volunteers have to pass some simple tests. A minimal amount of training is in fact needed to distinguish dust particles in the photographs (made by focusing at different depths within the aerogel) from defects present in the aerogel matrix.

But to observe the sky it's still necessary!

Other than the passive projects and the moderately active ones we have looked at above, there are also, fortunately, many others that can only be done by getting outside and looking at the sky.



Galactic collisions, such as NGC 6240, photographed here by the Spitzer Space Telescope, can have complex shapes that make them very difficult to classify by computers. [ESA/NASA]

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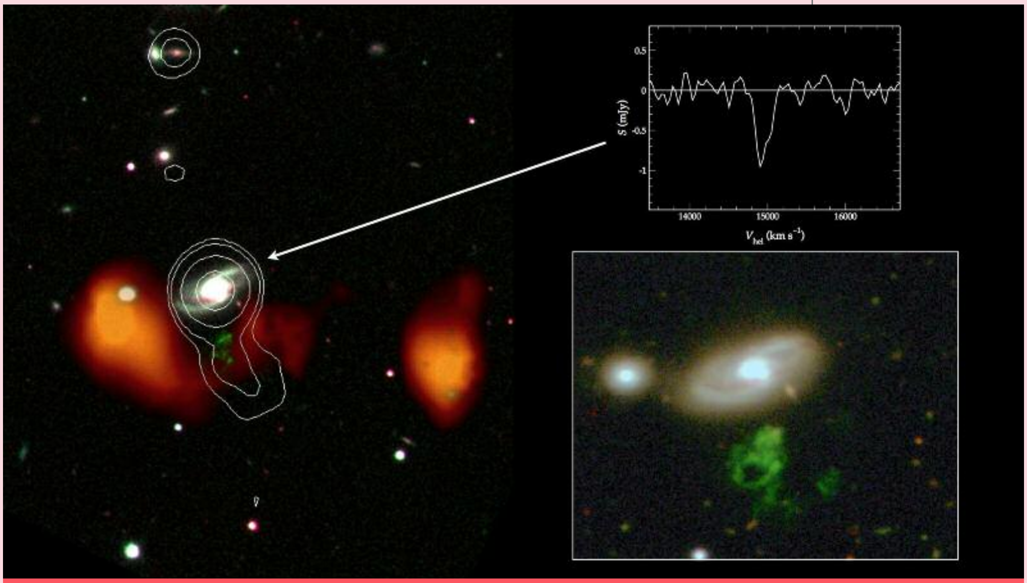
Hanny's object

A young Dutch music teacher, without any specific scientific training, now has her name associated with an unusual celestial object.
Hanny van Arkel was classifying galaxies from the Sloan Digital Sky Survey, just as innumerable other volunteers all over the world. Looking through the images supplied by the Galaxy Zoo web site Hanny, in fact, stumbled upon a rather bizarre image that she posted on the project's forum. Drawing attention to this "cosmic ghost", never before seen by human eyes, (just as most of the images dealt with by the project) the young teacher also drew the attention of professional astronomers.
At first it was thought that it could be a very distant galaxy, but the absence of stars, in what was already being called "Hanny's Object", indicated that it was instead a large gas cloud. This made the situation more intriguing, because the cloud must be at a temperature of around 15,000°C to emit the light seen, but there are no nearby stars to provide the necessary energy. The most likely source of energy is radiation from a relatively nearby quasar; the nucleus of a galaxy made active by the infall of material onto its central black hole. The central region of the nearby spiral galaxy IC 2497 is inactive today, but in the past it may have shone so brightly that is would have been visible with an amateur telescope, even though it is 700 million light years away.
The intense radiation emitted by the quasar would have taken many thousands of years to reach the gas cloud, exciting it so that it would be visible by terrestrial telescopes. This is an effect similar to emission features seen near supernovae that exploded centuries ago, albeit on a much larger scale.
This phenomenon, commonly called "light echo", was first discovered at the start of the nineteenth century by the Dutch astronomer Jacobus Cornelius Kapteyn, around Nova Persei. The echo occurs when radiation from a very intense source hits a distant body and causes light to be emitted that reaches the Earth. The greater path traveled by the "reflected" light can reveal the existence of sources that have long been extinct.
What Hanny saw for the first time, probably indicates a past period of increased activity in IC 2497.



Recent observations reveal a radio jet (white contours) coming from IC 2497 and directed towards Hanny's Object (green, enlarged in the inset). The large reserves of hydrogen (orange) may be from an encounter with another galaxy. The strong absorption line of atomic hydrogen (graph at upper right) is evidence that the activity in the nucleus of IC 2497 is strongly obscured in the direction of Earth, due to gas and dust. Hanny's object appears green due to strong line emission from doubly ionized oxygen. [ASTRON and the Isaac Newton Telescope]

Hanny van Arkel, young Dutch music teacher, who while contributing to the Galaxy Zoo project, discovered the object that now bears her name. [Courtesy Allard de Witte]

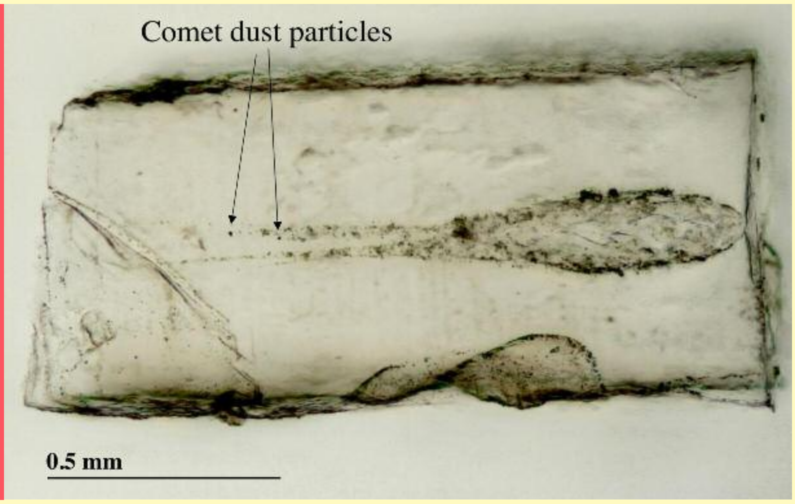
The distance between the cloud and the galaxy, between 50,000 and 80,000 light years depending on the projection angle, suggests that the activity in the nucleus must have ceased a similar amount of time ago. However, studies at various wavelengths, using both ground and space-based telescopes, have recently placed doubt on this explanation. Observations by the Westerbork Synthesis Radio Telescope (WSRT) and Very Long Baseline Interferometry (VLBI) Network, at frequencies of 1.4 and 4.9 GHz, have shown radio emission from the nucleus of IC 2497 that extends towards Hanny's Object. This would seem to suggest that the nucleus is still active, but in this case the cloud discovered by the Dutch teacher would not be an isolated object, but rather part of a larger structure.

A well aligned jet of relativistic particles, perpendicular to the disk of the galaxy, may have opened up a gap in the opaque interstellar medium, and caused the enormous 16,000 light year hole seen in this more extended cloud. In this way, the intense ultraviolet radiation from the active nucleus could have heated and ionized a small region of the cloud, situated on the outskirts of IC 2497.

This enormous gaseous structure, extending for more than 350,000 light years to the west of the galaxy and with a mass of around 5 billion solar masses, could be the result of an interaction of IC 2497 with another galaxy that occurred a few hundred million years ago. 57

The lack of X-ray detection of the nucleus of IC 2497 by the SWIFT satellite suggests, however, that the nucleus is completely shielded from direct view from the Earth.

While scientists continue to work to understand Hanny's Object we should remember that this strange object lay hidden in the archives for years, before being discovered by an amateur astronomer with a few clicks of a mouse. The chance adventure of this young music teacher shows how Citizen Science is producing completely new scenarios that help reduce the distance between the amateur and the professional astronomer.

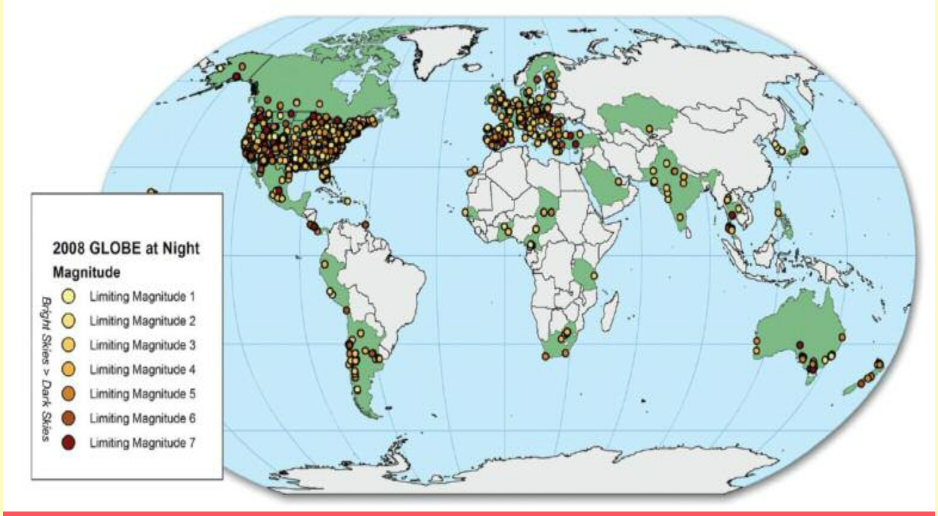


The Stardust@Home project aims to find microscopic dust particles trapped in the aerogel matrix used in the Stardust mission. The image illustrates the effects of the impact of microscopic cometary particles, in this case arriving from the right. [NASA/JPL]

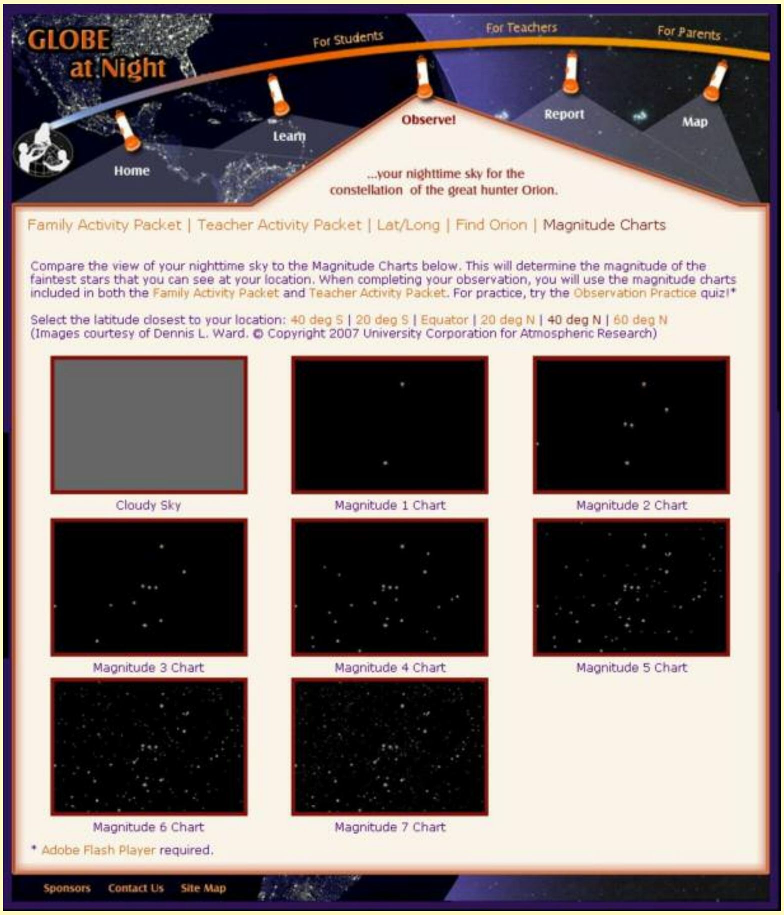
One of the simplest is GLOBE at Night, that produces maps of global light pollution. The main goal of this project, aimed at school students, is to raise awareness of the need for both public and private lighting to be more considerate to those that enjoy looking at the night sky. Volunteers all over the world are asked to check the state of their local night sky, either with the naked eye or with a kind of exposure meter. The simplest way of participating is by comparing the constellation of Orion with seven maps, provided by the project, in order to select that which best represents what you see. All that is then needed is to communicate the result, along with the relevant geographical coordinates, using the project web page.

Taking part in the activities of the AAVSO (mentioned above) however, requires significantly more skill and commitment.

This association, founded in 1911 at Harvard Observatory, coordinates amateur activities in the field of variable stars. Collaboration is open to all, and doesn't necessarily require the use of a computer because the results can be sent using conventional mail, as was done in the past. During its lifetime the AAVSO has collected around 17 million measurements, carried out by thousands of volunteers, contributing to numerous research programs. The amateur observations allow the monitoring of the brightest variable stars, difficult to study with large professional telescopes, and contribute significantly to the number of Galactic novae discovered every year.



The map shows the results on the state of light pollution from 6800 observations collected in 2008, via the GLOBE at Night project.



The simplest way to take part in GLOBE at Night is to compare the appearance of the constellation of Orion with the seven maps provided on the project web page. Simply select the map that most closely resembles what you see from your location.

The association makes available comparison charts which indicate the magnitude of stars similar in brightness to the variable under study, and also conduct various educational programs aimed mainly at teachers and students.

Conclusions

The main incentive that attracts thousands of people to contribute to Citizen Science programs is probably just fun, but there is also the attraction of being part of a community.

Participants can meet and interact in a virtual world via the main forms of social networking (e-mail, forums, blogs) both with the project leaders and with other volunteers. Apart from the intellectual benefits of being involved in a project there is also the satisfaction of contributing to the advancement of science.

Other incentives may be connected to the achievement of certain objectives: the Stardust@Home project, for example, will add to the author list of academic papers, the name of the person who found the grain of dust under investigation.

Teachers will find in these projects a particularly appealing way to introduce students to scientific methods. Citizen Science projects reduce the distance between scientists and the public, sometimes managing to overcome the indifference, or worse, diffidence, that some show for science that can seem far removed from their every day life.

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